APPLICATION UNDER UNITED STATES PATENT LAWS

Invention: **BI-DIRECTIONAL SCAN SWITCH MATRIX METHOD AND APPARATUS**

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<u>This is a</u>:

[ ] Provisional Application

[X] Regular Utility Application

[ ] Continuing Application

[ ] PCT National Phase Application

[ ] Design Application

[ ] Reissue Application

[ ] Plant Application

SPECIFICATION

BI-DIRECTIONAL SCAN SWITCH MATRIX METHOD AND APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to electronic input devices. More particularly, it relates to a multi-element switch matrix in which each rows and columns may be bi-directionally scanned to provide high input capacity.

2. Background of Related Art

A keypad may be one of the most common user interfaces to electronic equipment, e.g., a computer, a TV, or a VCR, etc. Typically, a keypad, e.g., on a computer keyboard or on a TV remote controller, includes a plurality of keys arranged in a matrix of rows and columns. A computer user or a TV viewer may input their commands to and/or interact with the computer or the TV by pressing a particular key among a plurality of keys on a keypad.

Typically, the pressing of a key mechanically moves one or more corresponding electrical contact(s) to come into physical contact with another, thereby making an electrical connection between them. Depending on the type of connection mechanism employed, the electrical connection may be only momentary (e.g., may be disconnected when the key is released) or can be persistent (e.g., may remain connected even after releasing of the key until deliberately disconnected, e.g., by pressing the key again).

One example of connection mechanism that provides a momentary electrical connection is a push button, which provides electrical connection only while a button is being pressed, and

disconnects when pressing is discontinued. On the other hand, a switch, once turned on, e.g., by pressing a key, remains on (i.e., connected) even if the key is released, until the switch is actively turned off, e.g., by pressing the key again, as is the case with a particular kind of switch called a toggle switch.

As with the keys, the corresponding connection mechanisms are also arranged in a matrix of rows and columns, typically referred to as a switch matrix. Thus, the position of each push button or switch within the matrix can be represented by a row and column coordinate, e.g., (row, col). For example, a push button located on the second row and at third column would have the coordinate (2, 3).

Typically, a switch matrix is "scanned" to determine which key is pressed. The scanning typically involves applying a known signal to a row, and examining each column. For example, if a signal level LOW was detected in column 2 while row 1 is being driven LOW, then the key at coordinate (1, 2) is determined as being pressed. This process is repeated for each of the rows, one row at a time, at a sufficiently rapid speed to detect even the briefest pressing of a key. With this scanning method, pressing of any key at any position within the matrix can be detected so long as only one key is pressed at a time.

As more and more advanced features are added to electronic equipment, the user interface thereto requires increasing number of keys. Unfortunately, the maximum number of keys a conventional switch matrix may scan and detect is limited to the product of the number of rows and the number of columns. For example, a conventional 4x4 switch matrix would support a maximum of 16 keys.

Thus, the size of conventional matrix must increase in order to accommodate increasing required number of keys, thus increasing the manufacturing cost of user interface devices.

Furthermore, a conventional scanning switch matrix can only accommodate momentary contact connection mechanisms, e.g., push buttons. Because a switch remains connected even after the release of the corresponding key, a sequential pressing of two keys would appear to a conventional scanning switch matrix as if the two keys were pressed simultaneously. Because a conventional scanning switch matrix can only detect one key press at a time, it cannot accommodate a switch.

Thus, if a user interface device requires both push buttons and switches, a dedicated detection mechanism must be provided for each switch in addition to the switch matrix. The additional detection mechanism adds complexity and cost to the user interface.

There is a need for a scanning switch matrix that is capable of accommodating more keys than the conventional maximum, i.e., the product of the number of rows and the number of columns.

There is also a need for more flexible and cost efficient switch matrix that allows integration of switches without the need for dedicated detection mechanism for the switches.

SUMMARY OF THE INVENTION

In accordance with the principles of the present invention, a switch matrix comprises at least one row conductor and at least one column conductor. At least one of the at least one row conductor and the at least one column conductor is capable of being driven with a predetermined voltage level, and is capable of having a voltage level read therefrom during a scanning of the switch matrix.

In accordance with an aspect of the principles of the present invention, a switch matrix comprises a plurality row conductors, a plurality of column conductors; and a plurality of switching elements adapted to connect at least one of the plurality of row conductors to at least one of the plurality of column conductors, The total number of switching elements

~~of the plurality of switching elements exceeds a product of a total number of row conductors of the plurality of row conductors and a total number of column conductors of the plurality of column conductors.~~

In accordance with another aspect of the principles of the present invention, a switch matrix comprises a plurality of row conductors, a plurality of column conductors, at least one switching element adapted to momentarily connect at least one of the plurality of row conductors to at least one of the plurality of column conductors; and at least one switching element adapted to persistently connect at least one of the plurality of row conductors to at least one of the plurality of column conductors.

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~~In accordance with the principles of the present invention, a method of scanning a switch matrix comprises, driving one at a time at least one of a plurality of row conductors with a predetermined voltage level. monitoring each of a plurality of column conductors while one of the plurality of row conductors is being driven with the predetermined voltage level, driving one at a time at least one of a plurality of column conductors with a predetermined voltage level, and monitoring each of a plurality of row conductors while one of the plurality of column conductors is being driven with the predetermined voltage level.~~

In accordance with yet another aspect of the present invention, a switch matrix may be scanned without the need of fast switching signals being present in the row and column conductors, thus eliminating the need for a AC de-coupling, or a noise and/or EMI filtering capacitor.

BRIEF DESCRIPTION OF THE DRAWINGS

Features and advantages of the present invention will become apparent to those skilled in the art from the following description with reference to the drawings, in which:

Fig. 1 is a simplified schematic of an exemplary 3x3 switch matrix, in accordance with the principles of the present invention.

Fig. 2 is a simplified schematic of an exemplary 3x3 switch matrix having integrated switches, in accordance with the principles of the present invention.

Fig. 3 is a flow chart showing the scanning of the exemplary 3x3 switch matrices shown in Figs. 1 and 2, in accordance with the principles of the present invention.

Fig. 4 is a simplified schematic of an exemplary hardware implementation of the scanning of the 3x3 switch matrix, in accordance with the principles of the present invention.

Fig. 4A is a timing diagram of scanning cycle of an exemplary 3x3 switch matrix shown in Fig. 4, in accordance with the principles of the present invention.

Fig. 5 is a simplified schematic of an exemplary hardware implementation of the scanning of the 3x3 switch matrix having integrated switches, in accordance with the principles of the present invention.

Fig. 6 is a simplified schematic of an exemplary conventional 3x3 switch matrix.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

The present invention provides a flexible and efficient switch matrix and scanning method thereof usable in user interface devices, e.g., a keypad or the like, having a number of connection mechanisms, e.g., push buttons and/or switches. A switch matrix device and scanning method thereof in accordance with the principles of the present invention is capable of accommodating a number of connection mechanisms up to twice the product of the number of rows and the number of columns.

A switch matrix device and scanning method thereof allows integration of one or more switches in the switch matrix without the need for additional detection mechanisms dedicated to the switches.

While, for the sake of brevity and clarity, an exemplary matrix having three (3) rows and three (3) columns, i.e., 3x3 switch matrix is described, the present invention is equally applicable to matrixes of any size, i.e., having any number of rows or any number of columns, and equally applicable to symmetrical matrixes, i.e., having equal number of rows and columns, as well as unsymmetrical matrixes.

Fig. 6 shows a simple exemplary conventional switch matrix with nine (9) connection mechanisms arranged as a matrix of three (3) rows and three (3) columns.

In particular, Fig. 6 shows nine (9) push buttons, **K1-K9**. Each of the nine push buttons **K1-K9** has a pair of electrical contacts **33** and **34**, and a connection button **35**. Each electrical contact **33** is connected to a row conductor **31** while each electrical contact **34** is connected to the column conductor **32**. The push buttons on the same column or on the same row share the same column conductor **32** or the same row conductor **31**, respectively. For example, push buttons **K1, K2** and **K3** share the same row conductor **31** of **Row 1** while push buttons **K1, K4** and **K7** share the same column conductor **32** of **Col. 1**.

In order to detect a push button being pressed, an algorithm is provided to scan each of the push buttons. During the scanning, a unique signal is applied to one row at a time and each of the columns is monitored for the presence of the unique signal. This process is repeated for each row, one at a time, on a rapid basis to ensure that even the briefest closure of a connection mechanism will be detected.

When the unique signal is applied to a particular row, the other rows are connected to a different voltage by high impedance to prevent excessive currents in the event that more than one switch in a

column is depressed. In a typical conventional circuit, the rows may be driven low and the columns are passively pulled high to a voltage level, e.g., to VCC or VDD, above the switching threshold of a monitoring circuitry, e.g., an input receiver of a controller (not shown).

When contacts **34** and **35** are disconnected (i.e., when the button **35** is not pressed), the column conductor **32** remains unconnected from the row conductor **31**. Thus, the voltage at the input of the receiver **36** remains high (e.g., at VDD), or at high impedance (e.g., tri-stated, Hi-Z). However, when the button **35** is pressed to bring the contacts **33** and **34** into an electrical connection, the conductors **31** and **32** are connected to each other. If conductor **31** is driven low, the voltage at the input receiver of the controller would be driven low. Thus, pressing of any push buttons **K1-K9** can be detected by driving each row LOW, and monitoring for a LOW voltage at each column,

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For example, assume that the push button **K5** (and no other push button at the same time) is pressed. The scanning algorithm would first drive **Row 1** Low (and drive **Rows 2** and **3** HIGH or high impedance (i.e., tri-stated output), and check the voltage levels of each of columns **Col. 1 – Co. 3**, one column at a time. Because the push buttons **K1-K3** were not pressed, a high voltage level, e.g., VDD, or a high impedance voltage level would be detected at each of columns **Col. 1 – Col. 3**.

The algorithm would then drive **Row 2** LOW (and drive **Rows 1** and **3** HIGH), and check the voltage levels of each of columns **Col. 1 – Co. 3**, one column at a time. Because the push buttons **K4** and **K6** were not pressed, a high voltage level, e.g., VDD, would be detected at each of columns **Col. 1 – Col. 3**. However, because **Row 2** would be driven LOW, a LOW voltage would be detected at **Col. 2** through the connection made between conductor **31** and conductor **32** via the connections between contacts **33** and **34** due to pressing of the button **35** at the push button **K5**.

When **Row 3** is driven LOW by the algorithm, and **Col. 1-Col. 3** are monitored, a HIGH voltage level or High Impedance level would be detected at each of the columns. Thus, a determination can be made that the push button **K5** was pressed by the fact that LOW voltage was detected only at the coordinate (2, 2), corresponding to the position of the push button **K5**.

Because of the sequential switching (e.g., from LOW to HIGH) at each of the coordinates, a very High frequency AC signal may be carried by each of the conductors **31** and **32**. The AC signals typically results in noise signals which must be minimized by the use of a low impedance AC shunt to ground for each row conductor **31** and column conductors **32** through an EMI capacitor **39**. Thus, in a conventional switch matrix, the use of the AC de-coupling (or EMI and/or noise filter) capacitor **39** is required for a proper operation.

Furthermore, it can be appreciated that the above-described conventional switch matrix requires that each crossing of a row and column conductors **31** and **32** has a single unique coordinate (Row, Column). That is any pair of a row conductor and a column conductor may be assigned one unique coordinate. Thus, for example, a pair of second row and third column would have a coordinate (2, 3). Thus, a conventional switch matrix can accommodate a maximum of rows x columns (e.g., 9 in the above 3x3 matrix example) of switching elements, e.g., buttons or keys, each button or key being uniquely addressable by the coordinate (Row, Column).

In contrast, the switch matrix **10** in accordance with the principles of the present invention shown in Fig. 1 may accommodate up to twice the size of the matrix, i.e., 2 x rows x columns, of push buttons, doubling the capacity of a conventional switch matrix. As will be explained, each crossing (or pair) of a row and a column can have two

unique coordinates, e.g. (Row, Column) and (Column, Row), thus can support up to two push buttons, each being uniquely addressable.

In particular, the switch matrix shown in Fig. 1 has two push buttons and a blocking diode **12** at each coordinate. Thus, the 3x3 switch matrix of Fig. 1 has 18 push buttons **KA-KI** and **K1-K9**, i.e., twice the product of the numbers of rows and columns.

Although the blocking diode **12** is shown in this example as being connected between switching elements **KA-KI** and the respective row conductor **31**, it should be readily apparent to one of ordinary skill that the diode may be placed in other places, e.g., between the switching elements **KA-KI** and the respective column conductors **32**, or between switching elements **K1-K9** and either the row conductors **31** or the column conductors **32** so long as it becomes forward biased when a respective row is driven LOW or when a respective column is driven LOW, but not when the respective row and column are both driven LOW.

Unlike a conventional switch matrix, the switch matrix in accordance with the principles of the present invention allows monitoring voltage levels of both the row conductors **31** and the column conductors **32**. Moreover, unlike a conventional switch matrix, the switch matrix of Fig. 1 allows driving both the row conductors **31** and the column conductors **32**. That is, both the row conductors **31** and column conductors **32** of the switch matrix in accordance with the principles of the present invention are bi-directional, and can be either an input or an output, at any given time.

The blocking diode **12** is reverse biased when the respective row conductor is driven LOW, and the corresponding switching element, e.g., the corresponding push button **KA-KI** is connected. Thus, even if the respective switching element **KA-KI** is connected, the corresponding row conductor **31** and the column conductors **32** remain disconnected to each other.

However, when a respective column is driven LOW, and the corresponding switching element **KA-KI** is connected, the diode **12** is forward biased, and thus the corresponding row conductor **31** and the column conductor **32** are connected. When columns are being driven, the voltage driven on the column conductor **32** (less the forward bias voltage drop over the diode which is typically on the order of half a volt) will be placed on the row conductor **31** if the corresponding switching element **KA-KI** is connected. Thus, by monitoring the voltage level of the respective row conductor, a closure of a switch element **KA-KI** may be detected.

Thus, it can be appreciated that closure of a switching element **K1-K9** can be detected by driving each row, one at a time, and monitoring each of the columns. Because the diode **12** is reverse biased when a row conductor **31** is driven LOW, any closure of switching elements **KA-K9** would not have any effect on the monitored voltages of any of the column conductors **32**. During this forward scanning (labeling only as a convenience, scanning where only the rows are driven will be referred hereafter as a forward scan, and scanning where only the columns are being driven will be referred as a reverse scan), closure of any of switching elements **K1-K9** can be detected.

During a reverse scan, when a column conductor is driven LOW, the corresponding diode **12** will be forward biased when the corresponding switching element **KA-KI** is connected, and thus any closure of switching elements **KA-KI** can be made as described previously.

Thus, during a forward scan, coordinates can be expressed as (Row, Column) as was the case with a conventional switch matrix. However, during a reverse scanning, a coordinate (Column, Row) may be provided. Unlike a conventional switch matrix, in a switch matrix in

accordance with the principles of the present invention, a coordinate (Row, Column) is unique from a coordinate (Column, Row).

For example, in a conventional switch matrix, a coordinate (Row =2, Column = 3) and a coordinate (Column = 3, Row = 2) describe the same switching element, namely **K6**, i.e., the one present at the crossing of the second row conductor and the third column conductor. In a switch matrix in accordance with the principles of the present invention, a coordinate (Row =2, Column = 3) and a coordinate (Column = 3, Row = 2) describe two different switching elements, namely **K6** and **KF**, respectively.

By alternating a forward scan and a reverse scan in one scanning cycle as shown in Fig. 1A, all eighteen switching elements can be monitored for their closure.

Fig. 2 shows another exemplary switch matrix having integrated persistent connection switches, in accordance with the principles of the present invention.

In particular, Fig. 2 shows a switch matrix **20** identical to switching matrix as Fig. 2 in every respect but having persistent connection switches **SWA-SWC** in three coordinates of the **column 1** in stead of the push buttons **KA, KD** and **KG**.

The switch matrix 20 operates essentially as the switching matrix **10** of Fig. 1 despite the inclusion of the switches **SWA-SWC**.

For example, during a forward scan, the switches **SWA-SWC** would not have any affect on the switching matrix because as with switching matrix **10**, the diodes **12** would be reverse biased, and the switches would be isolated from the row and column conductors.

During a reverse scan, because only one column driver **37'** is enabled at a time, and only one row receiver is read at a time, each of the switches **SWA-SWC** can be uniquely monitored to detect their closure.

For example, when **column 1** is driven LOW, and the receiver of **row 1** is read LOW, then the switch **SWA** must be closed, regardless of the status of other switches **SWB** and **SWC**. Thus, closure of any switches **SWA-SWC** can be uniquely detected.

It can thus be appreciated that persistent connection type switching elements can be integrated into the same switching matrix alongside temporary connection type switching elements scanned with the same scanning algorithm, without requiring a dedicated scanning or detection mechanism for either the persistent connection or the temporary connection type switching elements.

Fig. 3 shows a flow chart of scanning algorithm usable with the exemplary embodiments of the switch matrices according to the principles of the present invention as shown in Figs. 1 and 2.

In particular, during forward scanning steps **301-309**, each of the row conductors **31** is driven LOW (i.e., walking a zero), and the column conductors **32** are monitored one at a time to detect the closure, if any, of switch elements **K1-K9** as previously described. More particularly, in step **301**, the first row and the first column, for example, are chosen as the starting point of the forward scan. It should be apparent to and understood by one having an ordinary skill that the starting point need not be the coordinate (1,1), and may be any other coordinate. As shown in steps **304-307**, each of the columns 1 to n (e.g.,1 to 3 in 3x3 switch matrices as shown in the examples of Figs.1 and 2) are monitored (in step **305**) while each row **i** is driven LOW (step **303**). In step **306**, a determination is made whether or not all columns have been monitored (or read) by comparing the current column **j** with the maximum number of columns **n**, e.g., 3 in the examples of Figs. 1 and 2). In step **308**, a determination is made whether or not all rows had been driven LOW by comparing the current row **i** with the maximum number of rows **n**, e.g., 3 in the examples of Figs. 1 and 2).

During a reverse scanning steps **310-318**, each of the column conductors **32** is driven LOW (i.e., walking a zero), and the row conductors **31** are monitored one at a time to detect the closure, if any, of switch elements **KA-KI** as previously described. More particularly, in step **310**, the first row and the first column, for example, are chosen as the starting point of the reverse scan. It should be apparent to and understood by one having an ordinary skill that the starting point need not be the coordinate (1,1), and may be any other coordinate. As shown in steps **312-316**, each of the rows 1 to n (e.g.,1 to 3 in 3x3 switch matrices as shown in the examples of Figs.1 and 2) are monitored (in step **305**) while each column **i** is driven LOW (step **312**). In step **315**, a determination is made whether or not all rows have been monitored (or read) by comparing the current row **j** with the maximum number of columns **n**, e.g., 3 in the examples of Figs. 1 and 2). In step **308**, a determination is made whether or not all columns had been driven LOW by comparing the current column **i** with the maximum number of columns **n**, e.g., 3 in the examples of Figs. 1 and 2).

As can be appreciated, the bi-directional scanning switch matrix according to the principles of the present invention may be readily realized by a modification to the scanning algorithm as shown in Fig. 3. A further modification of the scanning algorithm for the embodiment shown in Fig. 2 can be minimized by ensuring that any individual column contains switching elements of the same type, i.e., either push buttons or switches.

Fig. 4 shows another embodiment of the switch matrix according to the principles of the present invention, with a hardware implemented scanning algorithm.

In particular, Fig. 4 shows a switch matrix **40** having three rows and three columns, i.e., a 3x3 matrix.

Each row conductor **31** is connected to an output of a driver **37**. A driver **37** may be, e.g., a line driver or an open collector amplifier,

etc. Each column conductor **32** is connected to an input of a receiver **36**. A receiver **36** may be, e.g., a line receiver or a detector amplifier. The receiver **36** may be Schmidt triggered to account for the direction of transition (i.e., high to low or low to high) of signal at the input of the receiver **36**.

Each row conductor **31** and each column conductor **32** are pulled high to a voltage level above the switching threshold of the receiver **36**, through a pull-up resistor **38**. Typically, the row and column conductors are pulled up to voltage level equal to the supply voltage of the electronics in the device, usually denoted as VCC or VDD.

The pull up resistors **38** must be large compared to the intrinsic resistance in the conductors **31** and **32**, and the expected contact resistance of the button **35** and the contacts **33** and **34** in order for proper detection threshold to be reached when keys are depressed. The pull up resistors **38** must also be large in case many keys in the matrix are depressed at once, which effectively places the pull up resistors **38** in parallel.

In contrast to a conventional switch matrix, the switch matrix of the present invention may be scanned by applying a level voltage, e.g., level LOW voltage and level High Impedance voltage, no AC noise signal may be present in the conductors **31** and **32**. Thus, although the embodiments of Figs. 4 and 5 show optional EMI capacitors **39** for protection against electro-static discharge (ESD) damages, the capacitors **39** are not necessary .for proper operation of the switch matrices shown in Figs. 4 and 5. Thus, the present invention provides switch matrices that can be properly scanned without the need for Ac coupling capacitors.

The row conductors **31** and the column conductors **32** are arranged and operate similarly as those of the conventional switch matrix shown in Fig. 6 as previously described.

In addition, the switch matrix shown in Fig. 4 has two push buttons and a blocking diode **12** at each coordinate. Thus, the 3x3 switch matrix of Fig. 1 has 18 push buttons **KA-KI** and **K1-K9**, i.e., twice the product of the numbers of rows and columns.

Although the blocking diode **12** is shown in this example as being connected between switching elements **KA-KI** and the respective row conductor **31**, it should be readily apparent to one of ordinary skill that the diode may be placed in other places, e.g., between the switching elements **KA-KI** and the respective column conductors **32**, or between switching elements **K1-K9** and either the row conductors **31** or the column conductors **32** so long as it becomes forward bias when a respective row is driven LOW or when a respective column is driven LOW, but not both times.

Fig. 4 further shows receivers **36** on both the row conductors **31** and the column conductors **32** to allow monitoring voltage levels of both the row conductors **31** and the column conductors **32**.

Furthermore, the switch matrix of Fig. 4 includes outputs of the drivers **37** being connected to both the row conductors **31** and the column conductors **32** to allow driving both the row conductors **31** and the column conductors **32**.

Thus, both the row conductors **31** and column conductors **32** of the switch matrix in accordance with the principles of the present invention are bi-directional, and can be either an input or an output, at any given time.

The drivers **37** each has a tri-state output, and includes an enable input (shown as a bubble) by which the driver **37** may be enabled to output a predetermined voltage level, or may be disabled to output a high impedance signal, which may be considered as disconnecting the output from the row or column conductors. That is when a driver **37** is

disabled, it appears disconnected (or open) to the respective row or column conductor.

Each of the selection signals **SEL (0), SEL (1)** and **SEL (2)** are produced, for example, under the control of a scanning algorithm for scanning the switching matrix of Fig. 1 for a presence of a closure of a switching element **KA-KI** and **K1-K9**, and select which driver **37** is to be enabled.

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The forward or reverse signal **FOR/REV** together with the selection signals is used to select which driver **37** is to be enabled, and also supplies LOW signal to the input of drivers **37**. The OR-Gates **13** ensure that the row drivers **37** are enabled only when both **FOR/REV** signal and the respective selection signal are low, and that the column drivers **37** are enabled only when the inverse of **FOR/REV** signal and the respective selection signal are bot low. The inverter **11** inverts the **FOR/REV** signal to ensure that the rows or the columns are not both enabled at the same time. The truth table for the **FOR/REV** signal and the selection signals with respect to the selection of a driver to be enabled is shown in Table 1 below.

Table 1

FOR/REV	**SEL (0)**	**SEL (1)**	**SEL (2)**	**Driver 37' output of**
0	0	1	1	Row 1 LOW, all other Hi-Z
0	1	0	1	Row 2 LOW, all other Hi-Z
0	1	1	0	Row 3 LOW, all other Hi-Z
1	0	1	1	Col. 1 LOW, all other Hi-Z
1	1	0	1	Col. 2 LOW, all other Hi-Z
1	1	1	0	Col. 3 LOW, all other Hi-Z

The scanning algorithm cycles through the above sequence of signals of $\overline{\textbf{FOR}}$/**REV**, **SEL (0)**, **SEL (1)** and **SEL (2)** as shown in table 1 above.

The blocking diode **12** is reverse biased when the respective row conductor is driven LOW, and the corresponding switching element, e.g., the corresponding push button **KA-KI** is connected. Thus, even if the respective switching element **KA-KI** is connected, the corresponding row conductor **31** and the column conductors **32** remain disconnected to each other.

However, when a respective column is driven LOW, and the corresponding switching element **KA-KI** is connected, the diode **12** is forward biased, and thus the corresponding row conductor **31** and the column conductor **32** are connected. When columns are being driven, the voltage driven on the column conductor **32** (less the forward bias voltage drop over the diode which is typically on the order of half a volt) will be placed on the row conductor **31** if the corresponding switching element **KA-KI** is connected. Thus, by monitoring the voltage level of the respective row conductor, a closure of a switch element **KA-KI** may be detected.

Thus, it can be appreciated that closure of a switching element **K1-K9** can be detected by driving each row, one at a time, and monitoring each of the columns. Because the diode 12 is reverse biased when a row conductor **31** is driven LOW, any closure of switching elements **KA-K9** would not have any effect on the monitored voltages of any of the column conductors **32**. Thus, during this forward scanning (labeling only as a convenience, scanning where only the rows are driven will be referred hereafter as a forward scan, and scanning where only the columns are being drive will be referred as a reverse scan), closure of any of switching elements **K1-K9** can be detected.

During a reverse scan, when a column conductor is driven LOW, the corresponding diode **12** will be forward biased when the corresponding switching element **KA-KI** is connected, and thus any closure of switching elements **KA-KI** can be made as described previously.

Thus, during a forward scan, coordinates can be expressed as (Row, Column) as was the case with a conventional switch matrix. However, during a reverse scanning, a coordinate (Column, Row) may be provided. Unlike a conventional switch matrix, in a switch matrix in accordance with the principles of the present invention, a coordinate (Row, Column) is unique from a coordinate (Column, Row).

For example, in a conventional switch matrix, a coordinate (Row =2, Column = 3) and a coordinate (Column = 3, Row = 2) describe the same switching element, namely **K6**, i.e., the one present at the crossing of the second row conductor and the third column conductor. In a switch matrix in accordance with the principles of the present invention, a coordinate (Row =2, Column = 3) and a coordinate (Column = 3, Row = 2) describe two different switching elements, namely **K6** and **KF**, respectively.

By alternating a forward scan and a reverse scan in one scanning cycle as shown in Fig. 4A, all eighteen switching elements can be monitored for their closure.

As shown in Fig. 4A, a complete scanning cycle may include time periods **t1-t18**, each of which correspond to a reading of a particular row or column conductor **31** and **32** by a corresponding receiver 36 while a particular row or column conductor **31** and **32** is being driven LOW.

For example, during the time periods **t1-t9**, **FOR/REV** is low, and the signal from the inverter **11** is HIGH, thus all column drivers **37** are disabled, and appear to column conductors **32** as if they are entirely

absent. Thus, during the time periods **t1-t9**, a forward scan is performed, i.e., rows are driven and columns are monitored.

During the time periods **t1-t3**, **row 1** (by keeping the selection signals at 011 to enable only the driver **37** of **row 1**) is driven LOW, and each column is read by the respective receiver **36**, e.g., **column 1** is read during time period **t1**, **column 2** is read during time period **t2**, etc. In this manner status of all nine switching elements **K1-K9** are checked during the forward scan period, i.e., **t1-t9**.

Immediately following the forward scan, i.e., during time periods **t10-t18**, the scanning algorithm would produce a HIGH **$\overline{\text{FOR}}$/REV** signal, which disables all row drivers **37** to output high impedance signal. The column drivers **37** are driven LOW, one at a time, and each of the row receivers **36** is read as shown. Because the LOW signal at the cathodes of the diodes **12**, the diode **12** is forward biased if the corresponding switching element, i.e., the corresponding one of the push buttons **KA-KI**, is closed. Thus, when one of the switching elements **KA-KI** is closed, the corresponding row receiver **36** will read the LOW voltage (with the forward voltage drop of the diode added) when the corresponding column is driven LOW.

Thus, switching elements **KA-KI** are monitored during the reverse scanning period, **t10-t18**, and all switching elements **K1-K9** and **KA-KI** are monitored during a complete scan cycle **t1-t18**.

Fig. 5 shows another exemplary hardware embodiment of the switch matrix having integrated persistent connection switches, in accordance with the principles of the present invention.

In particular, Fig. 5 shows a switch matrix **50** identical to switching matrix as Fig. 4 in every respect but having persistent connection switches **SWA-SWC** in three coordinates of the **column 1** in stead of the push buttons **KA, KD** and **KG**.

The switch matrix **50** operates essentially as the switching matrix **40** of Fig. 4 despite the inclusion of the switches **SWA-SWC**.

For example, during a forward scan, the switches **SWA-SWC** would not have any affect on the switching matrix because as with switching matrix **50**, the diodes **12** would be reverse biased, and the switches would be isolated from the row and column conductors.

During a reverse scan, because only one column driver **37** is enabled at a time, and only one row receiver is read at a time, each of the switches **SWA-SWC** can be uniquely monitored to detect their closure.

For example, when **column 1** is driven LOW, and the receiver of **row 1** is read LOW, then the switch **SWA** must be closed, regardless of the status of other switches **SWB** and **SWC**. Thus, closure of any switches **SWA-SWC** can be uniquely detected.

It can thus be appreciated that persistent connection type switching elements can be integrated into the same switching matrix alongside temporary connection type switching elements scanned with the same scanning algorithm, without requiring a dedicated scanning or detection mechanism for either the persistent connection or the temporary connection type switching elements.

While the switching matrix and method according to the principles of the present invention have been described particularly with reference to a preferred embodiment using an exemplary circuit implementation, the present invention may be implemented with any such variation of the circuits capable of allowing bi-directional scanning of the switch matrix while ensuring alternatively driving and reading columns and rows, i.e., ensuring that both rows and columns are not driven at the same time.

Furthermore, while the switch matrix in accordance with the principles of the present invention is described using an exemplary embodiment showing three integrated persistent connection switching

elements, the present invention may be implemented with any number of such persistent connection switching elements, in any position within the switch matrix, either in the forward scan group or reverse scan group, or monitoring memory access by a processor, and capable of overlaying system and/or user definable information in a faster memory.

While the invention has been described with reference to the exemplary embodiments thereof, those skilled in the art will be able to make various modifications to the described embodiments of the invention without departing from the true spirit and scope of the invention.